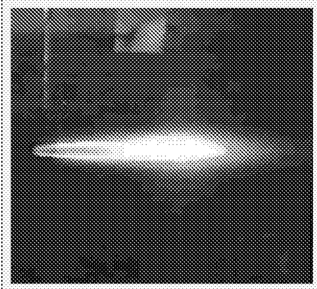
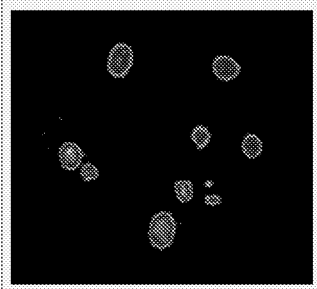
Studying Fires in Orbit

Combustion Module–2 (CM–2)

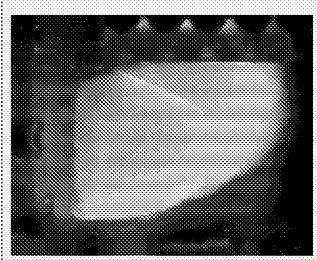
CM–2 Experiments



Laminar Soot Processes (LSP): Evaluate and predict flame shape and internal structures; determine the nature of the soot emission process; validate new universal equations for soot and temperature in a flame; and investigate the soot-bursting hypothesis. Results will improve our understanding of turbulent flames found in many combustion devices on Earth.



Structures of Flame Balls At Low Lewis-Number (SOFBALL–2): Improve our understanding of the flame ball phenomenon and lean (low fuel) burning combustion; determine the conditions under which they can exist; test predictions of duration; and derive better data for critical model comparison. Results will lead to improvements in engine efficiency, reduced emissions, and fire safety.



Mist: Measure the effectiveness of fine water mists to extinguish a flame propagating inside a tube to gain a better understanding of the mist fire-suppression phenomenon. What is learned will help us design and build more effective mist fire-suppression systems for use on Earth, as well as in space.

Light a candle and it quickly forms the familiar teardrop shape caused by hot, spent air rising and cold, fresh air flowing in behind it to keep the fire going. But this airflow also obscures many of the fundamental processes that we need to understand if we are to fine tune the many ways we control combustion in manufacturing, transportation, heating, fire safety and pollution.

Conducting combustion experiments in the microgravity environment of orbit eliminates gravitational effects and slows many combustion processes so they become easier to study. Almost everything about fires changes in microgravity, and many differences are counter-intuitive:

- Microgravity fires may spread faster upwind than downwind, opposite to the behavior seen on Earth,
- While fire in space is often weaker than on Earth, flames in microgravity can be sustained under more extreme conditions than flames on Earth, and
- Turbulent flames, thought to be completely independent of gravitational influence, have doubled in size in microgravity conditions.

Professor Gerard Faeth at the University of Michigan has said that these findings show that gravity has impeded the rational development of combustion science much as the atmosphere has impeded astronomy.

To build on what we have learned from space about combustion, the STS–107 mission will refly the Combustion Module that flew on the Microgravity Sciences Laboratory 1 and 1R (STS–83 and –94) in 1997. Upgraded and designated CM–2, the module will accommodate three experiments, Laminar Soot Processes (LSP–2), Structure of Flame Balls at Low Lewis-number (SOFBALL–2), and Water Mist Fire Suppression Experiment (Mist).

LSP–2 and SOFBALL–2 are reflights from the Microgravity Sciences Laboratory 1; Mist is a new experiment. They are detailed in separate fact sheets.

CM–2 will complete the primary science plan for these investigations, and help set the stage for expanded, long-term experiments aboard the *International Space Station* with the Fluids and Combustion Facility that will be installed in Destiny, the U.S. lab module.

Project Manager: Ann Over, NASA Glenn Research Center, Cleveland, OH
Deputy Project Manager: David Frate, NASA Glenn Research Center, Cleveland, OH
CM-2 Science Contact: Dr. David Urban, NASA Glenn Research Center, Cleveland, OH

Background Information

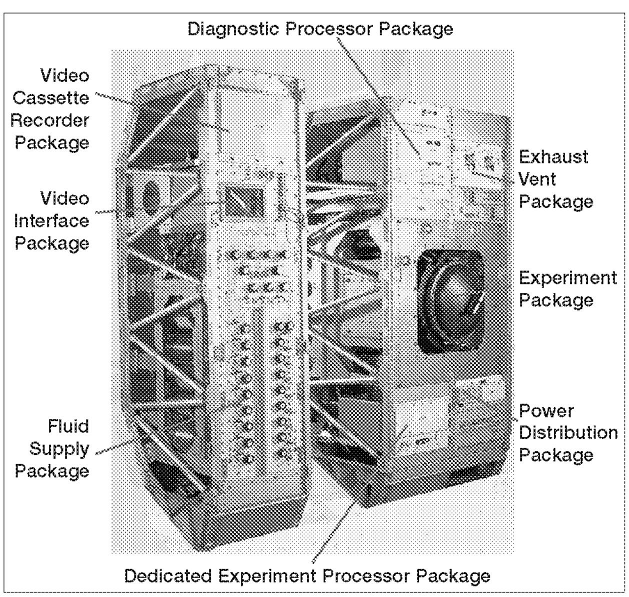
CM–2 Background

The Combustion Module (CM) is a state-of-the-art space laboratory to let a wide range of users perform combustion experiments in space. Until 1997, combustion experiments were developed for individual experiments. This was time-consuming and costly. NASA decided that a better and less expensive approach was a reusable, modular combustion facility that could accommodate diverse experiments with the same support hardware and unique Experiment Mounting Structures (EMS). This approach led to the CM.

CM–2 Design

Most CM–2 subsystems are in a double rack and a single rack standing side-by-side in the SPACEHAB module. Flight spares and EMS's are carried in a Maximum Envelope Stowage System that is the same size as a double rack. Central to the CM–2, in the double rack, is the Experiment Package, a 90-liter combustion chamber with six ports for three intensified near-infrared cameras, one color camera, and three black and white cameras; a gas chromatograph; crew switches; and thermistors. The Fluid Supply Package, in the single rack, is a complex gas control and distribution system containing 20 composite overwrapped compressed gas bottles.

The Videocassette Recorder Package consists of four Hi-8 video recorders. The Exhaust Vent Package includes a blower, canister, and other fluid components for cleanup and evacuation of chamber gases. The Dedicated Experiment Processor Package is the main processor for experiment command and control, and connects to the crew laptop (the CM–2 human interface). The Video Interface Package is the primary video interface for switching, routing, and display. The Diagnostic Processor Package is the video frame grabber and storage system for digital data. The Power Distribution Package controls and conditions the power from the Shuttle/SPACEHAB for all CM–2 packages. Finally, the EMS are experiment-unique chamber inserts. Each contains an ignition system and special sensors; the Mist EMS also contains test gases, a water mist generator, and a canister to remove water and carbon monoxide after each test.



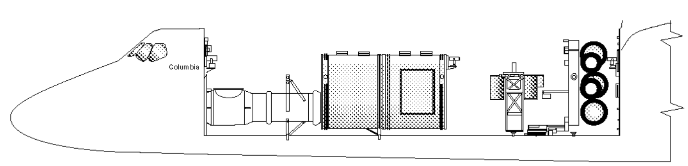
CM–2 Statistics

Size: Main racks — 2.13 m tall by 1.52 m wide by 0.91 m deep (7×5×3 ft)
Weight: Main racks — 835 kg (1840 lb); other CM–2 hardware — 161 kg (355 lb)
Subsystems: Eight rack-mounted components, three chamber inserts
Power Usage: Average — 419 W (dc);Peak — 543 W (dc)
Chamber Size: 40 cm (16 in.) dia. × 76 cm (30 in.) long; 91 liters (23.4 gal.) empty
Cameras: Seven — one color, three intensified near-infrared, three black and white
Lasers: Two sets of low-power beams for LSP and Mist measurements
Sensors: Dozens of pressure, temperature, and radiation sensors
Gas Analysis: Gas chromatograph determines percent of each kind of gas
Gas Bottle Sizes: 21 — three × 10 liters, nine × 3.8 liters, eight × 0.7 liters, one × 0.4 liters
Gas Bottle Usage: Fourteen SOFBALL mixes, two air, two LSP fuel, three gas chromatographs
Software: Three 25 MHz computers, ~35,000 lines of code
Video: Four VCRs, frame grabber, and two-channel downlink capability; 15.2 cm (6-in.) diagonal screen onboard
Data: 13.3 gigabytes storage (20 hard drives/flash memory cartridges)
Crew Time: 92 hours

Flight Operations

Although the flight crew is in the spotlight for shuttle missions, a team of engineers, scientists, and other support personnel on the ground will make it all possible. The CM–2 team, comprising almost 40 engineers and scientists, will work side-by-side with the NASA Johnson Space Center Mission Control team in Houston, TX. For STS–107, 16 days of around-the-clock operations are conducted to ensure safety and mission success. The CM–2 experiments timeline spans the entire mission.

The LSP experiment includes 15 burns lasting about five minutes each, with active participation by the crew to adjust test conditions during the burn. The 15 SOFBALL burns range from 25 to 167 minutes each, during which the Shuttle is placed in "free drift" with no attitude control so that the flame balls float freely inside the combustion chamber. The crew checks on the flame balls every ten minutes and adjusts camera gains as needed. The 36 Mist burns are each very short ranging from less than one second to several seconds in duration. Mist includes six tests run by the crew and 30 tests run by the ground team using commands sent directly to CM–2's on-board computer.



Approximate location of this payload aboard STS–107.

Photos. Page 1 from top: University of Michigan at Ann Arbor, University of Southern California, Colorado School of Mines; page 2, NASA.

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